

# Plate meter for estimating pasture mass in an Appalachian silvopasture

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Key words: agroforestry, forage, plate height, ruler height, tall fescue,  
orchardgrass

## ABSTRACT

Throughout the summer of 1999, a standardized plate meter for measuring pasture mass was calibrated at the Agroforestry Research and Demonstration Site in Blacksburg, VA. Calibration took place on six ungrazed plots of native tall fescue (*Festuca arundinaceae*) overseeded with orchardgrass (*Dactylis glomerata*). Each of the six plots were previously interplanted in 1993 and 1994 with bare root honeylocust (*Gleditsia triacanthos*) and black walnut (*Juglans nigra*) seedlings spaced along a gradient ranging from 1.8m (6ft) to 11m (36ft). Plate height (PH) of forage between the trees was measured by placing a 46cm x 46cm x 5.6mm-thick acrylic plastic plate meter on the pasture canopy at six random locations four times from May to July. Plate height was measured between the ground and the 3.8cm-center hole of the plate as it rested on the pasture canopy. To calibrate the plate meter against a known dry matter (DM) yield, 50cm x 50cm plots were clipped following each PH measurement. The resulting calibration regression slope was  $421\text{kg (ha cm)}^{-1}$ , with an  $r^2$  of 0.86. The relatively high  $r^2$  is attributed to the consistency of the plate meter as well as the wide range of plate heights measured. Ruler height (RH) of forage grass was also compared against PH. The resulting regression slope was  $1.71\text{cm (cm)}^{-1}$ , with an  $r^2$  of 0.87, showing good correlation between RH and PH, attesting to the plate meter's value as a research and extension tool.

Using the plate meter calibration equation, estimated pasture mass from 241 sample points were compared against corresponding point elevations to determine if there was a forage growth response due to elevation. In spite of the 30m elevation difference at this site, no significant correlation was found between estimated forage dry matter yield and topographic elevation, possibly due to the insensitivity of the device for discrete point sampling.

## INTRODUCTION

Efficient resource management is integral to any land use system. Landowners who invest time and energy planting trees in their pasture need some assurance that the resulting silvopasture will develop productively with an ongoing economic return. With that goal in mind, a simple and inexpensive method of measuring pasture mass was calibrated and tested at Virginia Tech's agroforestry research and demonstration site, located on the 600-ha Kentland Agricultural Research Farm (figure 1).

[insert Figure 1]

Honeylocust (*Gleditsia triacanthos*) and black walnut (*Juglans nigra*) seedlings were planted in 1993 and 1994 in the resource allocation study area in order to study basic tree and pasture interactions. The 1-ha resource allocation study is made up of six small plots consisting of tree seedlings planted in ungrazed native tall fescue (*Festuca arundinaceae*) pasture overseeded with orchardgrass (*Dactylis glomerata*). Both grass species are cool-season grasses suitable for livestock grazing. The need for a fast and accurate method to evaluate forage mass (i.e., dry matter yield) in silvopastoral research trials was the basis for the present study. The objective of this study was to obtain a calibration equation for the plate meter to be used for future forage mass determinations at the agroforestry research and demonstration site.

Several researchers have reported higher forage production under black walnut trees than in adjacent, open fields (Smith 1942; Neel 1939; Garrett and Kurtz 1983). Other researchers (Akbar et al. 1990; McClaran and Bartolome 1989; Ratliff et al. 1991) have observed increased cereal crop and pasture yields under hardwood trees. According to Rayburn (1998), several methods have been developed for estimating pasture mass, including ground cover methods, canopy height, the product of ground cover and canopy height, bulk height of the forage canopy compressed by a weighted disk or board, and an electronic capacitance meter. Testing of these methods has been done by several researchers over the years, including Bransby et al. (1977); Evans and Jones (1958);

Griggs and Stringer (1988); Michalk and Herbert (1977); Neal and Neal (1973); Pasto et al. (1957); Sharrow (1984); and Vartha and Matches (1977). Several of these studies have demonstrated that the ground cover method predicts pasture mass of low-yielding grasses such as blue-grass (*Poa pratensis* L.), but is less accurate in more productive orchardgrass and/or legume pastures. The weighted disk selected for the present study is well-documented, inexpensive, and easy to use, making it well-suited for temperate silvopastoral research and extension work.

The study site is located at 37°11' N latitude and 80°35' W longitude approximately 16km southwest of the Virginia Tech campus in Blacksburg, Virginia in the Southern Appalachian Ridge and Valley Physiographic Province. Elevation of the site is approximately 540m (1760 feet) above MSL, with annual temperature ranging from -20° C (-4°F) in the winter to 33°C (92°F) in the summer. Mean annual temperature is 10°C (50°F) and average annual precipitation is 1500mm (60in). Soils at the site are Typic Hapludults, which are generally older, deep well-drained soils with gently sloping to steeply sloped topography (25-65% slope). Depth to water table is generally greater than 2m.

## MATERIALS AND METHODS

### Calibration Study

A 46-cm square (0.21m<sup>2</sup>) by 5.6-mm acrylic plastic plate meter (Rayburn 1998) was calibrated on six ungrazed silvopasture plots between May and July of 1999 using four pairs of clipped plot and plate height (PH) data. Silvopasture plots were dominated by native tall fescue (*Festuca arundinaceae*), with orchardgrass (*Dactylis glomerata*) as a secondary species. Lesser numbers of other grass species and legumes such as red clover (*Trifolium pratense*), hairy vetch (*Vicia villosa*), and white clover (*Trifolium repens*) were also present in the sward. At the time of the study, black walnut seedlings had an average basal diameter and height of 3.2cm (1.3in) and 105cm (40in), respectively. Honeylocust seedlings had an average basal diameter and height of 3.9cm (1.5in) and 237cm (93in), respectively. In each plot, trees were planted along a gradient ranging from 1.8m (6ft) to 11m (36ft), within and between trees. All trees in the study received a

herbicide application of glyphosate in the spring at a rate not exceeding 40ml/gal. All plots had been fertilized in prior years. Composite soil sampling showed normal pH and organic matter levels and no apparent deficiencies of nitrogen or phosphorus.

Plate height and ruler height were measured at each sample point between the ground and the 3.8cm-center hole of the plate as it rested on the pasture canopy. The technique for determination of ruler height and plate height follows. A wooden measuring stick was first lowered until it touched the ground, with the measuring plate held above the grass. The plate was lowered slowly until leaves of grass were touching the plate in three of the four plate quadrants. The measured height at this point is “ruler height” (RH). [Ruler height is the measure most often used by farmers to visually assess forage quantity.] The plate was then allowed to drop until its full weight was supported by the grass. The measured height at this point is plate height (PH).

Four sets of field calibration data consisting of RH and PH were taken on May 27, June 11, June 29, and July 28. Sample dates were selected to obtain the widest range of grass heights for a good calibration. Six random sample points were taken on each of the above dates outside the perimeter of the silvopasture plots for a total of 24 sample points. A validation data set was not taken due to time and labor constraints. Calibration points were located outside the study plots because of the destructive nature of the clipped plots. After each RH and PH measurement was recorded, a 50cm x 50cm PVC clip-plot frame was laid over the plate meter on the ground and over the sample point. The plate meter was then removed and the grass along the edges of the PVC frame separated to allow the frame to rest squarely on the ground. Standing biomass was removed from within the PVC frame as close as possible to the ground using hand clippers. Freshly clipped forage from each sample point was placed in paper bags, individually marked, then stored in a walk-in dryer at 55 to 65°C for a minimum of 5 days. After drying, clipped forage was weighed, then discarded. Resulting dry matter (DM) yield, in kg/ha, was plotted against PH, in cm, and regressed to determine the best-fit calibration equation. RH was also plotted against PH to derive a field conversion factor from RH to PH.

### Elevation Study

In the summer of 1997 and 1998, at the agroforestry research and demonstration site, the volumetric moisture content of the soil in the adjacent silvopastoral study area (figure 1) was measured via permanently installed TDR (time domain reflectometry) instrumentation. Bendfeldt et al. (1998) determined at that time that the volumetric soil water content in the silvopastoral study site declined uniformly with increased elevation. As a follow-up, in the present study forage response (via dry matter yield) was compared against site elevation to determine if there was a relationship between the two.

To obtain an acceptable sampling regime over the 1-ha resource allocation study area, 100 randomly-generated points were identified on a 10m-GPS (geographic positioning system) grid map of the site. Sample points were then placed (semi-permanently) on the ground using brightly painted 6-inch nails with 2-inch washers flush with the soil surface. All points were assigned a number and flagged so they could be relocated after pasture cuttings. PH measurements were taken on each point on May 1, May 21, and July 16 before the 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> cuttings, respectively. Fifty-nine of the 300 total sample points taken were unusable because sample points fell either within herbicide-sprayed areas adjacent to tree seedlings or in excessively overcut or tractor-damaged portions of the plots.

Each of the remaining 241 sample points used for the elevation study were assigned an elevation using a site contour map developed from a GPS-controlled ground survey. Using the derived equation from the calibration section of this paper (equation 1, below) a dry matter (DM) forage yield was estimated for each PH measure. Individual DM yields were then plotted against corresponding topographic elevations to determine if there was a forage response to the suspected moisture gradient at this site.

## RESULTS

Table 1 presents the results of the calibration study, showing mean and standard deviation for RH, PH, and DM yields for each of the four sampling periods. Overall means are also presented.

[insert Table 1]

Figure 2 shows the resulting relationship between DM yield and PH, as determined from clipped plots. The regression equation for the best-fit line was

$$PM = 421 PH + 941 \quad (1)$$

where PM is estimated pasture mass, dry matter yield (kg/ha) and  
PH is measured plate height (cm).

The  $r^2$  for calibration equation 1 was 0.86. The relatively high  $r^2$  for this calibration is likely due to the consistency of the plate meter, as well as the wide range of plate heights selected for the calibration set.

[insert Figure 2]

Figure 3 shows the graphical relationship between RH and PH. The regression equation for the best-fit line was

$$RH = 1.71 PH - .387 \quad (2)$$

where RH is ruler height (cm) and  
PH is plate height (cm).

The  $r^2$  for the calibration equation 2 was 0.87, attesting again to the consistency of the plate meter as well as the relatively wide range of ruler heights selected.

[insert Figure 3]

Table 2 and figure 4 present the results of the elevation study. Table 2 shows mean and standard deviations for all 241 measured PH and estimated DM determinations over the three sample periods. Overall means and standard deviations are also presented. Figure 4 presents the resulting linear regression between DM yield (kg/ha) and topographic elevation. In spite of the relatively high  $r^2$  (0.83) obtained, the graph shows little impact of elevation on PM as measured by dry matter yield.

[insert Table 2 and Figure 4]

## DISCUSSION AND CONCLUSIONS

Using the plate meter described in this paper, and more fully detailed by Rayburn (1998), a calibration equation (equation 1) was developed for use by researchers at the agroforestry research and demonstration site. The resulting calibration equation can be used at the resource allocation site to estimate pasture mass from field-measured plate height data. Work reported by Rayburn (1998) and others emphasizes the need to take 30 or more observations when predicting pasture mass from calibration equations.

Using equation 2 of this paper, plate height values can be converted into the more easily understood grass or ruler height. In the absence of a plate meter device, plate height can also be derived from ruler height by solving equation 2 for PH. The resulting equation, which follows, can be used to convert ruler height into plate height (on those pastures for which they are calibrated).

$$PH = .584 RH + .226 \quad (3)$$

where PH is estimated plate height (cm) and  
RH is measured ruler height (cm).

The relationship derived above between PH and RH follows closely with results reported by Rayburn et al. (unpublished) in West Virginia where PH was equal to .61RH. Within the limits of the calibration equation, pasture managers in West Virginia are encouraged

to use a 15-cm (6-in) plate height as a maximum goal height for rotational grazing or haying, which corresponds to approximately a 25-cm (10-in) ruler height. For practical on-farm use of the plate meter, Rayburn (1998) recommends additional calibrations over pastures differing in species composition, season of year, and regrowth age.

The expected result from the elevation study was a trend showing increased forage mass at lower elevations (assumed to be at a higher moisture gradient). Although results from this study showed no such relationship, figure 4 and table 2 did reflect the magnitude of the standard deviation present in the sample data. Perhaps figure 4 also illustrates the difficulty in using a single 46cm x 46cm quadrant to represent a discrete pasture mass (which seems logical given the high variability inherent in pasture swards).

Mean values of 7630kg/ha (6900lb/ac) for DM yield shown in table 2 for the tall fescue/orchardgrass swards in this study are in line with reported values for similar pastures. Taylor (1988) reported DM yields for tall fescue-red clover pastures in Kentucky of 12,200kg/ha (11,100 lb/ac). He also reported tall fescue pastures fertilized with 200kgN/ha yielding an average 10,900kgDM/ha (9900lb/ac). According to Taylor, tall fescue pastures fertilized with 100kgN/ha yielded an average 7400kgDM/ha (6700lb/ac), which is closely in line with the DM values found in the present study.

In conclusion, this plate meter calibration study appears to verify more rigorous previous work reported by others. Although the elevation study did not produce the expected results, it was learned that the strengths of the plate meter are in its pasture-wide estimations, not in its ability to predict a discrete point pasture mass. Overall, the plate meter appears to account well for inherent variations in a pasture sward resulting from species composition, season of year, and regrowth age.

### ACKNOWLEDGEMENTS

The author wishes to thank the following institutions and persons for their help in making this modest study possible. First, the USDA-ARS Lab in Beckley, WV provided much of the leadership and funding for the agroforestry research and demonstration site. Virginia Tech's Department of Forestry, headed by Harold Burkhart, has joined in this commitment to long-term agroforestry research, as has the staff at the Kentland Agricultural Research Farm, especially Dwight Paulette, John Wooge, and Romney Smith. Ed Rayburn of West Virginia University offered a lot of his time during the preliminary stages of this study, as did Virginia Tech faculty Paul Peterson, Ozzie Abaye, Jim Berkson, and Paul Mou. Last but not least, Forestry Department staff technicians and research assistants including Dave Mitchem, Eric Bendfeldt, Andy Scott, Brian Long, and Dia Anderson proved invaluable in making the work go smoothly throughout the hot, dry summer of 99.

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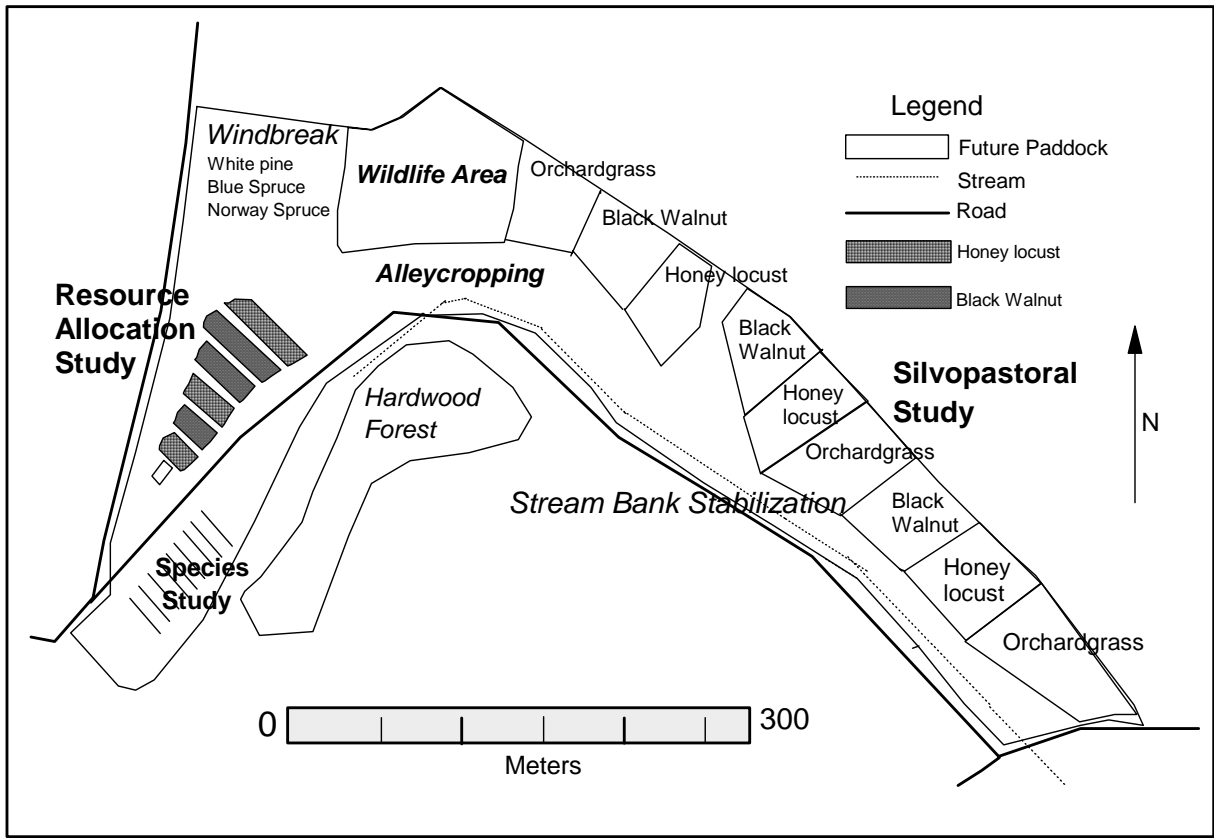


Figure 1. Kentland Farm Agroforestry Research and Demonstration Project, Blacksburg, Virginia.

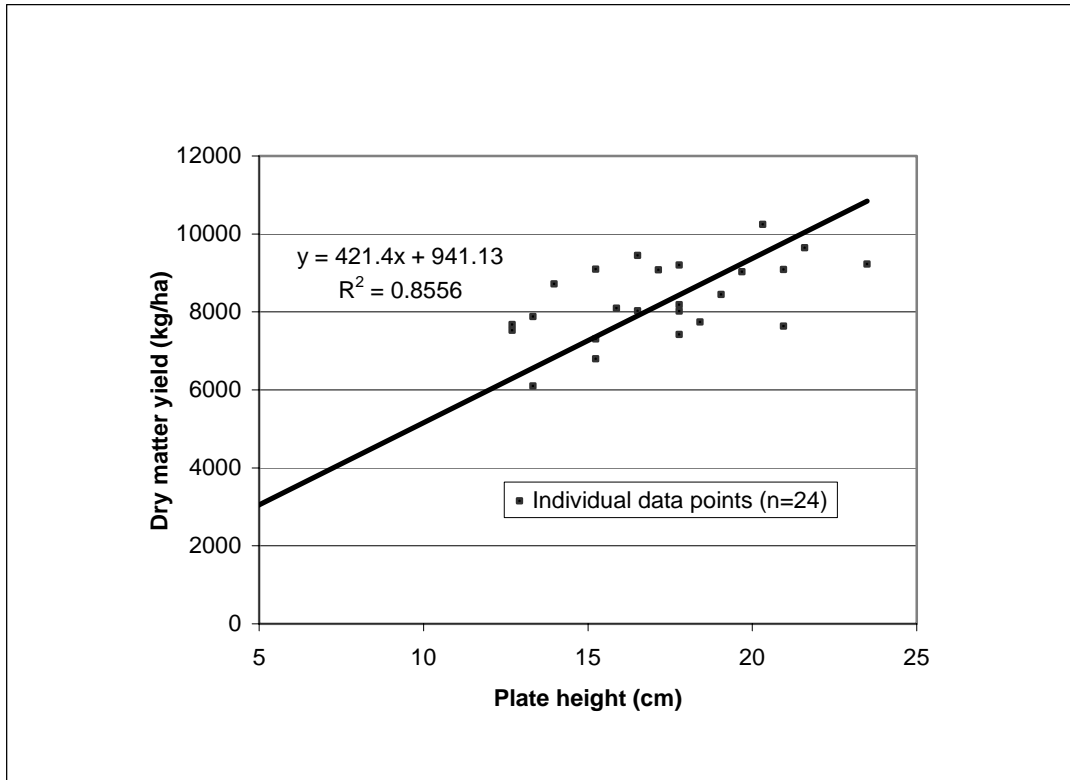


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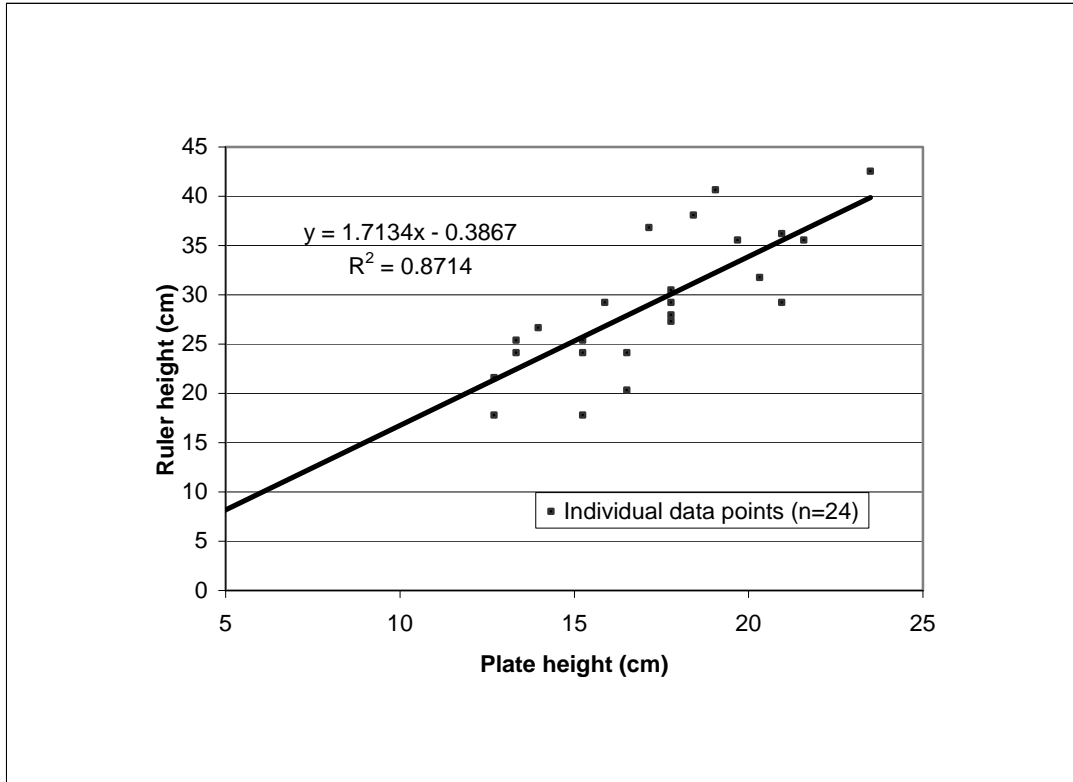


Figure 3. Ruler height (RH) vs. plate height (PH) (Kentland Farm, Blacksburg, VA, May-July, 1999).

Table 1. Description of six mechanically-cut silvopastoral plots used to calibrate plate meter (Kentland Farm, Blacksburg, VA, 1999).

Date	N	Ruler Height (RH)		Plate Height (PH)		Dry Matter (DM) Yield*	
		Mean (cm)	SD	Mean (cm)	SD	Mean (kg/ha)	SD
27-May (after 1st cutting)	6	34.6	5.4	18.8	2.7	8632	1068
11-Jun (after 2nd cutting)	6	21.6	3.9	15.2	2.1	8299	787
29-Jun (after 2nd cutting)	6	31.3	6.8	17.2	3.4	8419	988
28-Jul (before 3rd cutting)	6	28.8	4.3	17.7	3.0	7918	1171
Overall:	24	29.1	6.9	17.2	3.0	8317	981

\*based on .25m<sup>2</sup> quadrants clipped to the ground, and oven-dried at 55-65 degrees Celsius.

Table 2. Mean plate height (PH) measurements and estimated dry matter (DM) yields on mechanically-cut silvopastoral plots used for elevation study (Kentland Farm, Blacksburg, VA, 1999).

Date	N	Plate Height (PH)		Dry Matter (DM) Yield*	
		Mean (cm)	SD (cm)	Mean (kg/ha)	SD (kg/ha)
1-May (before 1st cutting)	93	15.6	3.7	7516	1556
25-May (before 2nd cutting)	63	18.2	3.2	8615	1342
16-Jul (before 3rd cutting)	85	14.5	3.2	7042	1339
Overall	241	15.9	3.7	7632	1550

\*Dry matter yield estimated from calibration regression equation  $PM = 421PH + 941$ .

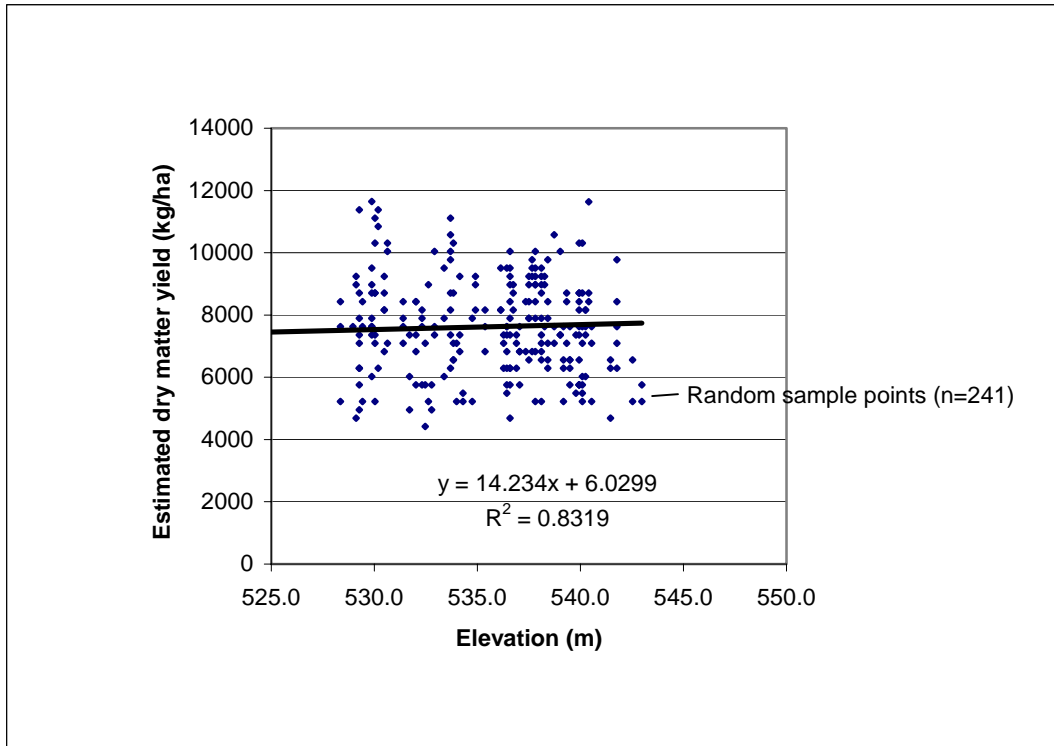


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